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INEQUITY ANALYSIS IN THE LOW AND HIGH COMPLEXITY PUBLIC SERVICES SUPPLY IN RELATION TO BEDS AVAILABILITY IN MANIZALES - VILLAMARÍA CONURBATION

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Abstract: This research aims to determine the current conditions of geographical accessibility to and from healthcare centres in Manizales and Villamaría conurbation through the Enhanced two- step floating catchment area (E2SFCA) method, supported by geographic tools and socioeconomic assessments. The main result is that the average number of beds per 1000 inhabitants in low complexity systems is below the average defined for Colombia and Latin America, thus requiring greater attention in implementing beds to reach the required accessibility levels. These valuations allow concluding that the accessibility of healthcare institutions requires the use of significant calculation tools, such as the E2SFCA method, which has not had great applications within the Colombian territory.

Key words: accessibility, geostatistics, mobility, E2SFCA, health

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INTRODUCTION

According to the Economic Commission for Latin America and the Caribbean - ECLAC (2020), Latin America is highly vulnerable due to its weak social protection and health systems and multiple levels of poverty and inequality. Due to this, strategies must continue to be sought to improve the Colombian health system, which guarantees access to health services for the population as a fundamental right and, at the same time, acts as the first resource for the defence of the population; the above in order to prevent/reduce the need for specialized care. It is essential to formulate accessibility measures that are reliable and accurate enough to identify the sectors with low health service coverage and thus allocate the necessary resources to reduce this problem to achieve this objective (Luo and Qi, 2009). Penchansky and Thomas (1981) define access to health care along five dimensions: affordability as the cost of using health care; acceptability, defined as the performance and satisfaction of health care delivery services; availability, defined as the number of points of care among which a user can choose; geographic acceptability, which is defined as the impedance of travel between providers and patients; and finally, accommodation defined as the capacity of health services. In turn, health care can be divided into two general phases: "potential", referred to as the potential for existing health care when the population coexisting in space and time requires such care, and "realized", which refers to when the service by health personnel is provided to the patient.

However, the availability of multiple healthcare service facilities leads to erratic behaviour in this care perception. Therefore, it is essential to examine together both the accessibility to these points and their availability, resulting in an assessment of spatial accessibility, as defined by Guagliardo (2004) and used in this research under the vision of "a potential measure for healthcare service provision", in search of identifying the underserved population as a first phase towards a government intervention (Luo and Qi, 2009). The study case to be analysed is the healthcare system in Manizales and Villamaría, setting as an obejctive to clarify the existence of unequal conditions in the geographical distribution of the beds available in the study area, both in the low and high complexity IPSs, determining the differences in coverage for the citizenship, as well as the approach of possible solutions in terms of implementation of services. Manizales, capital of the Caldas department, is located in the central-western zone of the Colombian territory at 2150 m.a.s.l and has an area of 442.01 km2 (Alcaldía de Manizales, 2016); Villamaría, is located in the central-southern zone of Caldas and has 461 km2 of surface (Alcaldía de Vilamaría, 2018). Figure 1 shows the location of the study area. According to DANE (2018), the urban area provides medical services to approximately 463,267 people.

The increased availability of relevant resources, such as population and transport route information, facilitates the deployment of valuable technologies for accessibility research, such as Geographic Information Systems (GIS). This

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technology enables creation of spatial distribution maps of healthcare needs and uses, through which the socio-spatial impact of health policy decisions can be assessed (McLafferty, 2003). Likewise, GIS can determine the accessibility condition to and from the nodes of interest (healthcare centres), considering socio-demographic and socioeconomic data and the number of available beds. Spatial accessibility is usually defined using a method to evaluate the population distribution of the health services available in the previously defined perimeter (Pan et al., 2015).

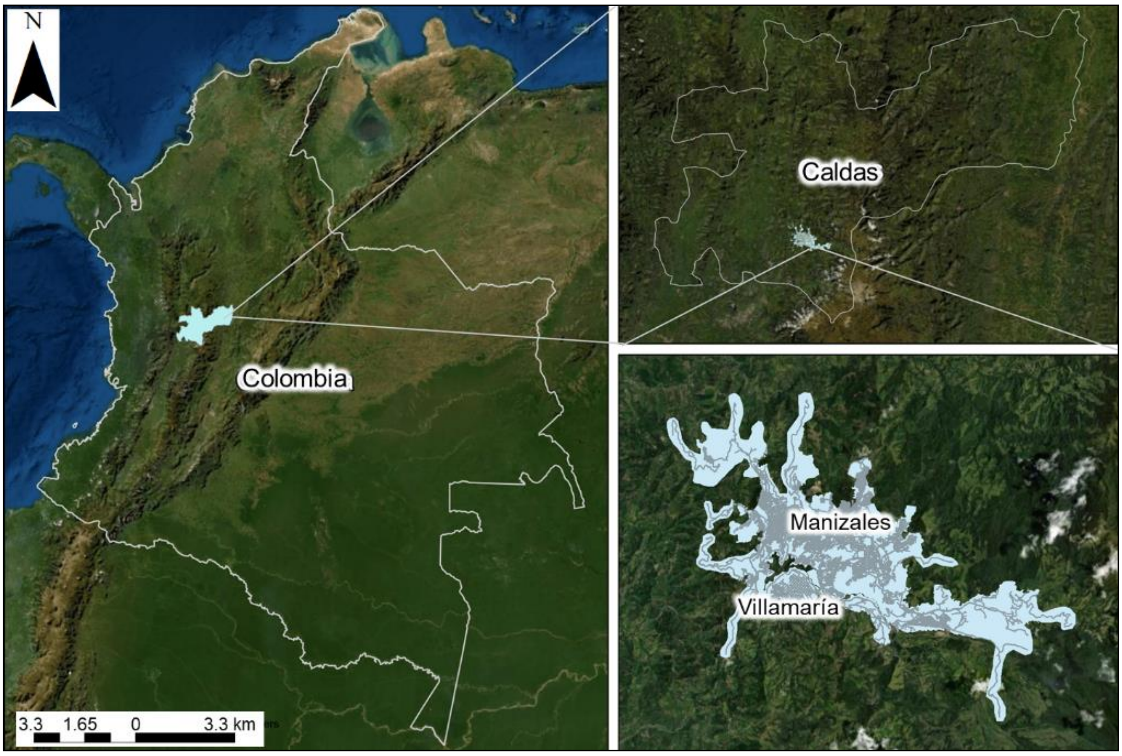

Figure 1. Location of Manizales City (Source: Self made)

There are different models for its measurement, such as gravity, regional availability, floating basin and core density (Guagliardo, 2004). However, despite the range of usable models, some of them may have very high accessibility ratings in some areas and underestimated in others, which leads to an incorrect distribution of available resources by the public administration (Luo and Qi, 2009). The Enhanced Two-Step Floating Catchment Area Method (E2SFCA) consists of dividing the areas into different sub-zones, which are attributed different values of importance according to the distance decrease f(d), adjustable according to the route (Pan et al., 2015).

Although it is known that other proposed methods share similarities with the Floating Catchment Method (2SFCA), however, E2SFCA will be used in this research, being this the most recommended floating catchment area method (Dewulf et al., 2013) and most used in the latest studies on the subject (Liu et al., 2022; Tali et al., 2023). In Colombia, applied research has been conducted in the healthcare field using the E2SFCA and 2SFCA methodologies, positively impacting the population (Escobar et al., 2020; Monsalve et al., 2016; Rojas et al., 2017), identifying important contributions in the way these methods are applied in Colombia and more in the field of health, in which little was known; facilitating the processes of localization of critical areas and expansion of services.

METHODOLOGY

The methodology used contemplates the use of 4 stages, which are shown in Figure 2 and described below.

Stage 1. Data Collection: As a first, the information required for the research, both primary and secondary, was collected, verified and filtered. This includes data on neighborhoods, population and socioeconomic condition of the conurbation area under study; likewise, the transportation network is structured, including arcs and nodes, considering the

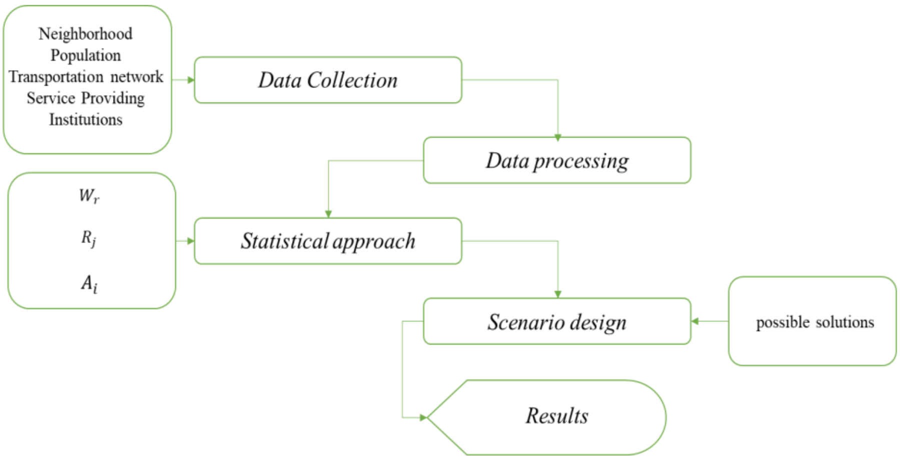

Figure 2. Methodology (Source: Self made)

physical and operational conditions of importance (speed, direction, length, slope). The Service Providing Institutions (IPS) are obtained from the base information provided by the Health Secretariat of both municipalities, which are spatially located according to the location defined by the entity. Likewise, a database is created containing information on the number of beds and the level of service of each IPS, information that is obtained by contacting each of these establishments and using the set of data provided by the Special Registry of Service Providers (REPS).

Stage 2. Data processing: Once the basic data has been collected, the sociodemographic information layer for the study area is organized, which includes neighborhoods, population and socioeconomic strata, which is understood as the subdivision into population groups considering the population's purchasing power, where stratum 1 represents the most unfavorable condition and stratum 6, the population group with the highest purchasing power. At the same time, the current condition of the transportation network is evaluated, updating and/or correcting sectors with inconsistencies through GPS applications, georeferencing the road arcs that are not in the layer and that are not yet in the ISRI application due to their recent construction or commissioning, verifying the structure according to the graph theory (Cardozo et al., 2009), evaluating the performance concerning topological conditions, as well as its physical and operational components mentioned above. The layer with the IPS geographic location is created based on the care level and the number of available beds. All the data collected is reviewed, adjusted and updated.

Stage 3. Statistical approach: As a next step, the integral accessibility calculation is performed. Its results are analyzed according to the average cost of user travel, establishing the level of coverage in the average travel time in the transport infrastructure network to the IPSs, taking as criteria the care level, the number of beds and the number of doctors available. The dataset of the Network is created to perform the integral accessibility calculation using the Network Analyst extension in ArcMap and subsequently perform the network analysis and obtain the minimum travel time vector.

Once the average travel time vector is constituted, the corresponding geographic coordinates of each node are assigned, continuing with the geostatistical model application of ordinary kriging interpolation, with linear semi-variogram as a structuring equation (Moncada et al., 2018). After this, the interpolations are reclassified into raster-type entities at 5-minute intervals, resulting in the isochronous curves of accessibility. Finally, they are associated with socioeconomic variables, resulting in the cumulative coverage percentage. Each catchment area must then be divided into sub-areas for the E2SCFA procedure application, setting a travel time threshold do, which allows the detection of areas with a shortage of healthcare employees, considering the development established by the U.S. Health Resources and Services Administration through the Health Professional Shortage Area (HPSA) tool. The threshold suggested by Lee (1991) of 30 minutes was used to determine the significant catchment area and thus be able to conclude whether the resources are near or far from the population, resulting in a sensitivity assessment with a temporal variation of between 20 and 50 minutes (Luo and Wang, 2003). After the analysis, it is concluded that 30 minutes of buffering corresponding to a 15-mile zone of influence is required to counteract the edge effect, considering the means of transport.

Work executed by Luo and Wang (2003) and Mao and Nekorchuk (2013) was conducted in the metropolitan areas of Chicago and Florida (USA), respectively. These areas have populations over 5 million, and both use a 30-minute do. To identify the increase/decrease in supply and demand, (Paez et al., 2019) use watershed methods such as SFCA and E2SFCA, employing time use data from the General Social Survey in Canada and considering the population of 720,000 and the density of the study area, the Hamilton CMA established a time threshold of 15 minutes.

Considering the above, it is decided to use the urban area of Manizales and Villamaría, which, according to DANE (2018), has a population density of 463,267 people and a travel time limit of up to 15 minutes. The W_r weights for each subzone are calculated at 5-minute intervals using an impedance function.According to Kwan (1998), three impedance functions are used for accessibility measures based on gravity: exponential function $f(d)=e^{-\beta d}$; inverse function $f(d)=e^{-\beta}$; and Gaussian function $f(d)=e(-dij^2/\beta)$, where β is defined as an impedance coefficient that measures the impact of travel costs (travel time or distance) on users' access to health services (Neutens, 2015). Of these impedance functions, Kwan (1998) asserts that the Gaussian structure (Eq. 1) better fits the standard distribution curve than the other structures. Wang (2007) points out that the exponential structure and the inverse obtain unrealistic accessibility models because they do not fit best to the standard distribution curve and show a sharp drop very close to the trip origin.

$$W_r = f\left(d_{ij}\right) = \exp\left(-\frac{d_{ij}^2}{\beta}\right) \tag{1}$$

Kwan (1998) establishes a critical value of 0.01 for the Gaussian impedance function (Eq. 1 Kwan, 1998) and, therefore, assumes this value for a driving time of 15 minutes (Wang, 2007). Clearing the impedance coefficient variable β yields a value of 34, which is substituted into the function for the other travel times, thus finding their respective weights. Individual section travel times are used as dij values for the calculation. Eq. 2 (Luo and Qi, 2009) shows the principle of the E2SFCA method, which measures the supply/demand ratio for each hospital Rj.

$$R_j = \frac{S_j}{\sum_{k\in\{d_{kj}\in D_r\}} P_k W_r} = \frac{S_j}{\sum_{k\in\{d_{kj}\in D_r\}} P_k W_1 + \sum_{k\in\{d_{kj}\in D_r\}} P_k W_2 + \sum_{k\in\{d_{kj}\in D_r\}} P_k W_3} \tag{2}$$

Where S_j is the number of hospital beds and P_k is the population in each of the travel time sub-zones (D1, D2, D3) corresponding to the 5-minute intervals in travel time, which are obtained from the transportation network. W_r is the distance weight for the rth travel time zone calculated from the Gaussian function, capturing the distance decay of access to the physician *j*. In the next step, all hospitals' demand and supply ratios for each population are summed according to their location. This is done by weighting the hospitals' location in the subareas according to Eq. 3 (Luo and Qi, 2009), which calculates the accessibility for the population of location *i* (A_i).

$$A_i = \sum_{j \in \{d_{ij} \in D_r\}} R_j W_r = \sum_{j \in \{d_{ij} \in D_1\}} R_j W_1 + \sum_{j \in \{d_{ij} \in D_2\}} R_j W_2 + \sum_{j \in \{d_{ij} \in D_3\}} R_j W_3 \quad (3)$$

Where A_i represents the accessibility of population at location i to physicians, R_j the physician-to-population ratio at physician location j that falls within the catchment centered at population i (that is, $d_{ij} \in D_r$), and d_{ij} the travel time between i and j. Eq. 3 is applied using the ArcMap Network Analyst software tool. The origin-destination matrix is obtained, and the average travel time is measured from the block centroids in the Manizales and Villamaría conurbation to the healthcare centres. Subsequently, using the Microsoft Excel tool, the appropriate weight (W_r) is indicated according to the range where the travel time is within the defined intervals of 5 minutes in the catchment area fixed at 15 minutes. Finally, the R_{ij} calculates the weights matrix product, which is the first step result.

These are added, and finally, the accessibility A_i is obtained, with which it is possible to determine the number of beds per thousand inhabitants in the conurbation of Manizales and Villamaría, differentiated by blocks. According to the publication of the Organization for Economic Cooperation and Development, entitled "Health at a Glance: Latin America and the Caribbean 2020", data are provided on the state of health and its determinants, among which information on coverage and service in Colombia stands out with an indicator of the availability of medical resources (number of beds per 1000 inhabitants) of 1.7 (OECD and World Bank, 2020). These indicators provided by the OECD are used as a basis for this research development, considering that the result provided by the organization focuses on the demand and supply of medical resources but does not consider the existing accessibility between travel to and from health centres. Next, the areas that show spatial inequities and/or inequalities in Manizales and Villamaría urban areas are identified and related to socioeconomic class and accessibility conditions. The relationship of A_{if} with the socioeconomic stratum of each block is established. Its average value is calculated for strata 1 to 6, allowing us to identify to which stratum the areas of low accessibility belong compared to the other areas.

Stage 4. Scenario design: Possible solutions are proposed to improve the accessibility conditions of the health centres by addressing the areas previously identified as the most underserved in the current scenario and proposing the activation of the health centres owned by E.S.E. Assbasalud (state social enterprise in charge of providing primary health services) already located in the area to take advantage of the existing infrastructure and location.

RESULTS AND DISCUSSION

The calculation of population coverage is analysed by considering socio-demographic and socio-economic assessments to understand the spatial effects of hospitals in terms of their location. Figure 3 and Table 1 shows the IPS that are part of this research with their geographical coordinates and the number of available beds. In addition, these IPSs are classified according to their level of complexity, data obtained from the Special Registry of Service Providers (Registro Especial de Prestadores de Servicios - REPS). Average travel times from each neighbourhood unit (i) to each hospital facility or IPS (j) were used to calculate the total number of users within the time windows of each IPS.

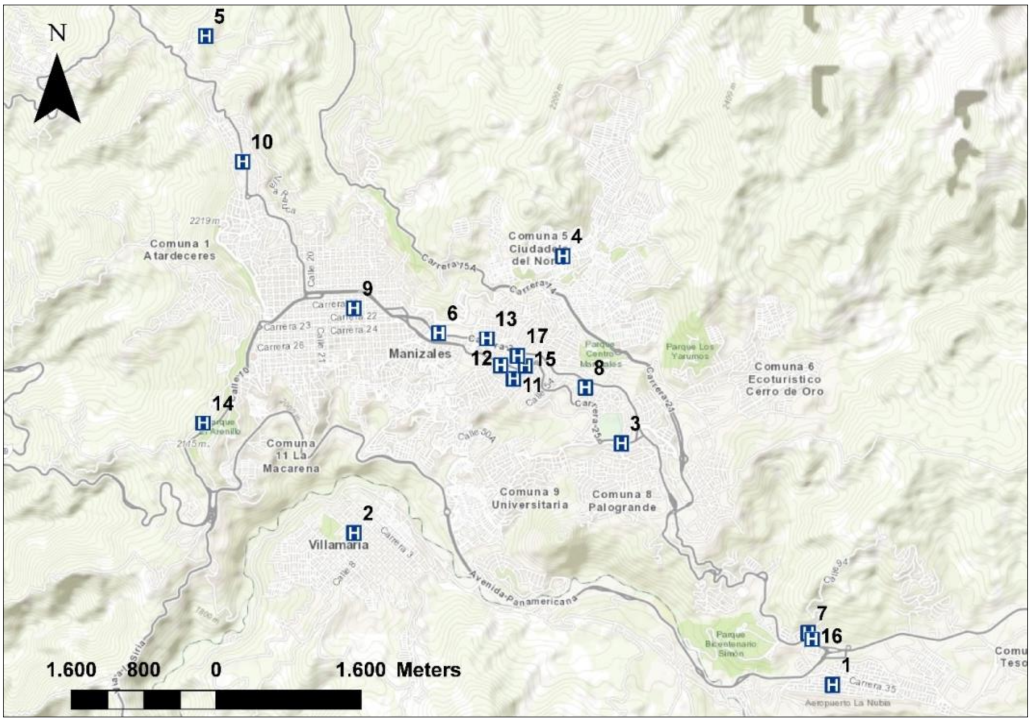

Figure 3. Location of IPS (Source: Self made)

This information estimates the ratio of health care points to population (R_j), i.e., to existing beds. Table 2 shows the number of users covered by the defined 15-minute catchment area in 5-minute intervals with the resulting R_{ij} in the current condition; then, Eq. 3 (Luo and Qi, 2009) is applied to obtain the accessibility rating A_i. Table 3 shows the accessibility values resulting from the E2SFCA method implementation in Manizales and Villamaría (study area) for the current scenario.

Table 1. Health provider institutions (IPS) in Manizales, current scenario (Source: authors) *In Colombia, the SES is an indicator associated to dwellings, which is related to the economic incomes of families. This indicator is used for subsidies allocation. There are 6 SES (1-6), where SES 1 corresponds to households with lower incomes and SES 6 to households with higher incomes.

ID	Name	Beds	Length	Latitude
Low-Complexity IPSs				
1	Clínica Assbasalud La Enea	24	-75,46728	5,03142
2	Hospital San Antonio	15	-75,51484	5,04645
3	Clínica Santa Ana	0	-75,48827	5,05532
4	Clínica Assbasalud San Cayetano	16	-75,49409	5,07384
High-Complexity IPSs				
5	Hospital General San Isidro	79	-75,52962	5,09561
6	Meintegral	46	-75,50643	5,06624
7	Oncólogos Del Occidente	110	-75,46968	5,03657
8	Clínica Su Vida Santillana	18	-75,49187	5,06084
9	Clínica Aman CMS	49	-75,51488	5,06868
10	Clínica Avidanti	262	-75,52593	5,08317
11	Instituto Medico Integrado	3	-75,49898	5,06169
12	Servicios Especiales De Salud Hospital De Caldas	164	-75,50028	5,06303
13	Clínica La Presentación	34	-75,50167	5,06568
14	Hospital Santa Sofia De Caldas	112	-75,52984	5,05732
15	Clínica Ospedale S. A	128	-75,49783	5,06299
16	Clínica CONFA Salud Sede San Marcel	79	-75,46933	5,03595
17	Hospital Infantil Universitario	71	-75,49859	5,06398

Table 2. First step, obtaining R_{ij} (Source: authors)

Name	Rij Beds	Population covered in each interval		
		5'	10'	15'
Low-complexity IPSs				
Assbasalud Clínica La Enea	4,60	4295,54	8035,57	10481,79
Hospital San Antonio	1,21	8093,31	28597,28	11910,97
Clínica Santa Ana	0,00	190,59	12696,56	33569,69
Assbasalud Clínica San Cayetano	1,98	5368,55	15854,47	57437,48
Hihgh-complexity IPSs				
Hospital General San Isidro	30,79	1748,11	5379,00	8150,98
Meintegral	10,80	394,49	17472,37	58438,76
Oncólogos Del Occidente	93,34	319,99	3864,71	17154,52
Clínica Su Vida Santillana	5,88	739,98	10536,84	42597,46
Clínica Aman CMS	8,58	1091,55	20530,18	86560,64
Clínica Avidanti	56,69	2750,14	11414,50	14870,97
Instituto Medico Integrado	1,01	1371,03	8149,50	27207,65
Servicios Especiales De Salud Hospital De Caldas	21,67	2710,94	24589,48	60196,23
Low-complexity IPSs				
Clínica La Presentación	11,70	23,32	12493,84	49252,37
Hospital Santa Sofia De Caldas	41,59	692,16	9438,44	30901,98
Clínica Ospedale S. A	50,46	18,01	10599,45	48989,16
Clínica CONFA Salud Sede San Marcel	45,35	88,33	7791,62	17689,46
Hospital Infantil Universitario	17,98	291,86	16185,81	60456,67

Table 3. Accessibility results in the current condition (Source: authors)

Beds Current Scenario					
Total average	**Total Maximum Value**	**Low complexity average**	**Low complexity maximum value**	**High complexity average**	**High complexity Maximum value**
3,17	116,29	0,13	3,83	3,04	115,41

Figure 4 shows the current low-complexity PHC accessibility regarding the number of beds using the E2SFCA method. Similarly, Figure 5 shows the current high complexity IPS coverage concerning the number of beds. In the current condition, an Ai accessibility rating of 3.17 beds per 1000 inhabitants is obtained. These results show a value of 0.13 for low-complexity IPSs and 3.04 for high-complexity IPSs, with an upper peak of 116.29 beds. The low-complexity IPSs are located in districts with high population density, such as Palogrande, Ciudadela del Norte, Universitaria, and Tesorito. High complexity IPSs are located along the Santander Avenue corridor, which has a higher commercial contribution and is less densely populated. The maps collected from the study area show a particular inequality regarding accessibility conditions. The Ciudadela del Norte, San José, Universitaria, Ecoturística Cerro de Oro districts, and the Municipality of Villamaría are identified as focal points.

The results show that inequality is more significant in the lower strata of the study area (strata 1, 2, and 3). In contrast, the higher strata (5 and 6) have adequate coverage concerning medical care in the case study. Based on this result, the proposal to improve this coverage focuses on improving the IPSs in lower-income areas. The suggested increase in beds is based on the Organisation for Economic Co-operation and Development's (OECD) work on health prospects in Latin America and the Caribbean, which places Colombia at an average of 1.7 beds per 1,000 inhabitants, 2.1 for Latin America and 4.7 for the organization's member countries (OECD and World Bank, 2020).

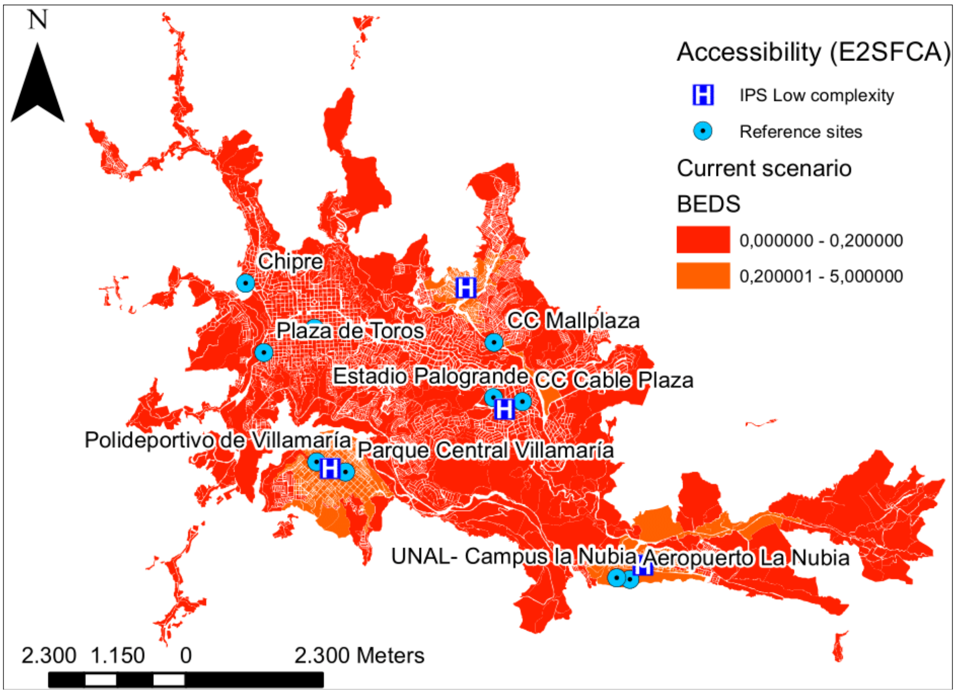

Figure 4. Accessibility assessment in low-complexity IPSs in current condition (Source: authors)

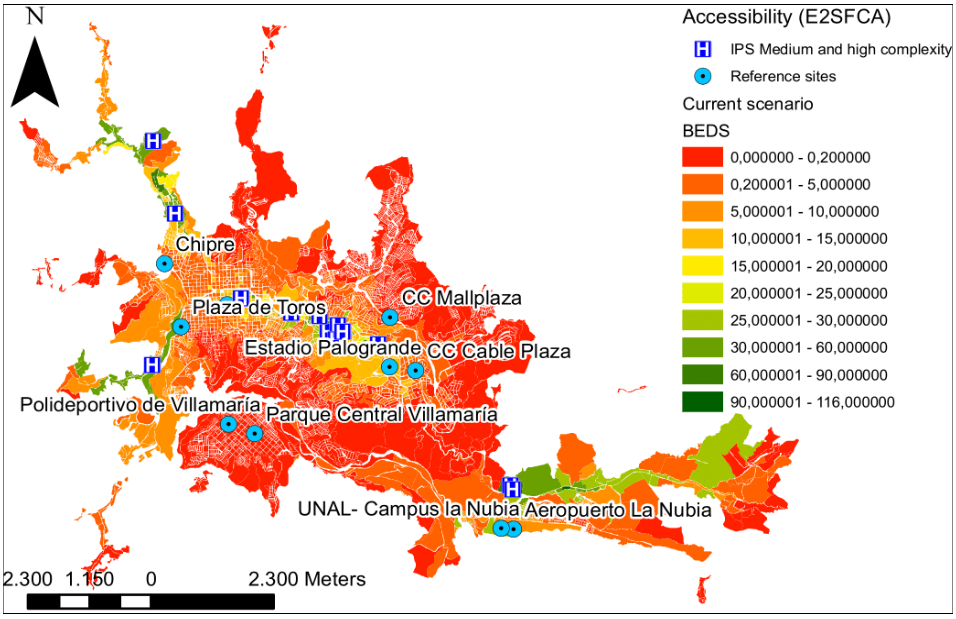

Figure 5. Accessibility assessment in high-complexity IPSs in the current condition (Source: authors)

Although the study area has an overall average of 3.17 beds per 1,000 inhabitants, higher than in Latin America, low-complexity PHRs have an average value of 0.13, well below the Colombian average. Therefore, improvements in the proposed scenario aim to intervene and increase the availability of beds in this type of service, allowing better accessibility for users and improving the competitiveness of the urban area compared to national-level actions. The number of beds continues to increase in the low-complexity IPSs of Santa Ana, Clínica Aman, and San Antonio, given the former's proximity to underserved areas, also increasing the level of service of Clínica San Cayetano to high complexity. It is proposed to reactivate the Assbasalud centres in the neighbourhoods of La Asunción, Minitas, Aranjuez, Fátima, and the pilot centre (of high complexity). This results in an 18% increase in beds, from 1210 to 1433 units. Table 4 shows the number of beds for this future scenario.

The gradient is estimated for low complexity Figure 6 and high complexity Figure 7 to compare current and future accessibility results calculated with the E2SFCA method. According to Figure 6, the percentage of savings in La Estación, Palogrande, Universitaria, and Ecoturismo Cerro de Oro districts is higher than 1000%. In these districts, the care centers in the neighbourhoods of La Asunción, Minitas, Aranjuez, and Fátima belonging to Assbasalud were activated with a low level of service. The savings gradient for high-complexity IPSs significantly impacts Ecoturística Cerro de Oro, San José, and Ciudadela del Norte's districts by improving the pilot centre and San Cayetano's service conditions, placing them as high-complexity IPSs. Figure 8 shows a graphical display of the relationship between the accessibility index, as reported by the E2SFCA A_{if} method, and socio-economic class regarding beds. Consequently, level 1 and level 4 represent entirely different situations, with the former (level 1) being the least accessible and the latter (level 4) the most accessible, giving similar results for high and low complexity. Low-complexity IPSs are primarily located in disadvantaged socio-economic levels. Thanks to this and the improvement proposal in this study, it is possible to achieve an improvement of 0.4 in the accessibility index for level 3, followed by an increase of 0.09 for level 2 in the future condition. For high complexity IPSs, which achieve the most significant improvement in level 2 with an improvement of 0.55, followed by level 3 with 0.33.

Table 4. Health care institutions (IPS) in Manizales, future scenario (Source: authors)

ID	Name	Beds	Length	Latitude
Low-complexity IPSs				
1	Assbasalud Clínica La Enea	24	-75,46728	5,03143
2	Hospital San Antonio	30	-75,51484	5,04645
3	Clínica Santa Ana	3	-75,48828	5,05533
4	Assbasalud Clínica San Cayetano	0	-75,49409	5,07384
Additions				
5	Assbasalud Fátima	20	-75,49835	5,05304
6	Assbasalud La Asunción	20	-75,49425	5,06876
7	Assbasalud Minitas	20	-75,47716	5,06442
8	Assbasalud Aranjuez	30	-75,50032	5,04252
Low-complexity IPSs				
9	Hospital General San Isidro	79	-75,52962	5,09561
10	Meintegral	46	-75,50643	5,06625
11	Oncólogos Del Occidente	110	-75,46969	5,03658
12	Clínica Su Vida Santillana	18	-75,49187	5,06084
13	Clínica Aman CMS	60	-75,51489	5,06869
14	Clínica Avidanti	262	-75,52594	5,08318
15	Instituto Medico Integrado	3	-75,49899	5,0617
16	Servicios Especiales De Salud Hospital De Caldas	164	-75,50028	5,06303
17	Clínica La Presentación	34	-75,50168	5,06569
18	Hospital Santa Sofia De Caldas	112	-75,52985	5,05732
19	Clínica Ospedale S. A	128	-75,49783	5,06299
20	Clínica CONFA Salud Sede San Marcel	79	-75,46934	5,03596
21	Sede Hospital Infantil Universitario	71	-75,49859	5,06398
Additions				
22	Assbasalud clinica san cayetano	60	-75,49399	5,07386
23	Assbasalud centro piloto	60	-75,51434	5,07188

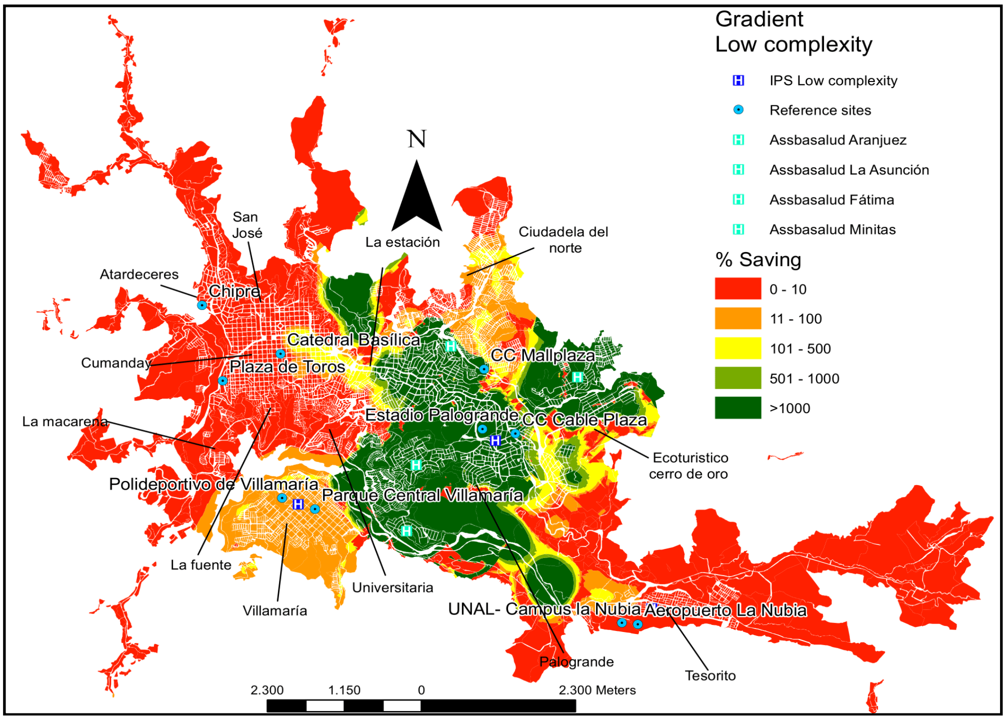

Figure 6. Savings gradient for low-complexity IPS beds (Source: authors)

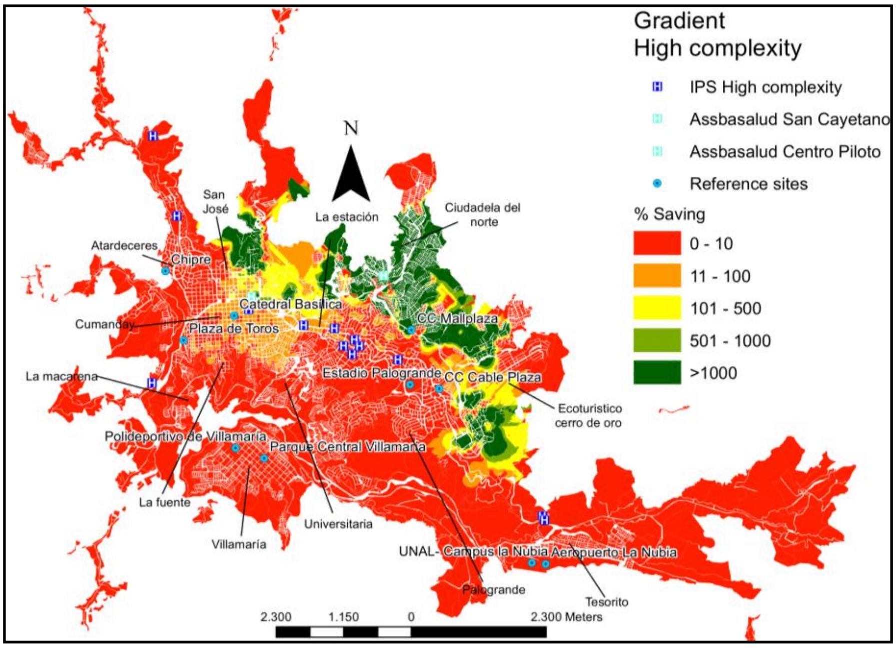

Figure 7. Savings gradient for high-complexity IPS beds (Source: authors)

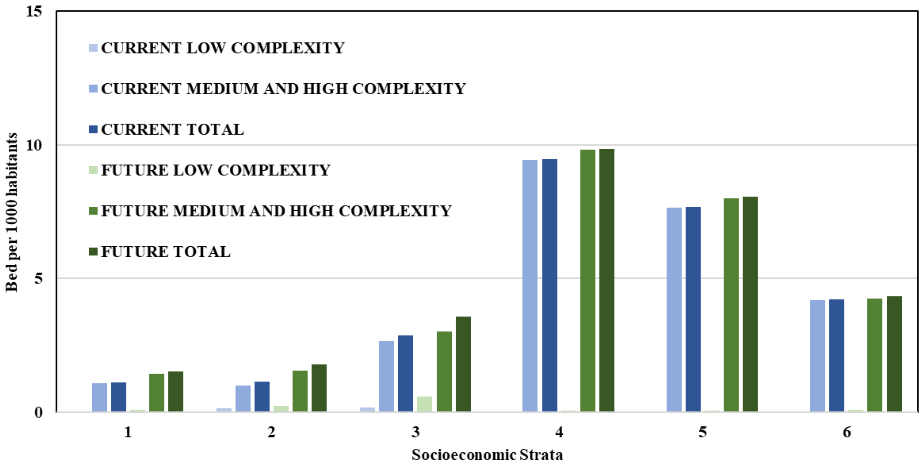

Figure 8. Stratification vs. Average number of beds per 1000 population (Current - Future) (Source: authors)

CONCLUSIONS

Based on this research work, the following conclusions can be drawn: 1) the E2SFCA method has been little applied in Colombia and Latin America concerning health issues. Although accessibility studies have been conducted for essential facilities for the population, such as healthcare centres, they have only been carried out considering geographical accessibility. This leads to a significant change, as the number of beds available in individual healthcare centres must be considered. 2) In Manizales and Villamaría urban areas, there is a significant gap between socio-economic classes concerning access to healthcare centres, with the middle and upper classes having the best care and the lower classes having the least. Activating the Assbasalud care centres proposed in this work will achieve better access to these services for the lower classes. However, it is still considered insufficient to achieve parity between classes. 3) This research will uncover areas where efforts and public funds should be directed to reduce the current inequities and inequalities regarding healthcare facility accessibility in the field of study. This points to the fact that the proposed methodology would provide a valuable tool for urban planning and equitable facilities development.

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